Livestock production from grazing is an integrated measure of the quantity and quality of forage consumed, which varies as a function of the quantity and quality of forage produced. Control of the intensity of defoliation is the basic principle of grazing management because it directly affects both ongoing and future levels of livestock production. Ongoing levels of production are affected because, as intensity of defoliation increases, livestock production generally increases up to some maximum before rapidly declining. However, future levels of livestock production are often depressed at high levels of grazing intensity because amount of residual plant tissue is less than that required to maximize post-defoliation forage production. It may be surmised, therefore, that the major challenge in grazing management is to balance these antagonistic relationships over time and space.

This is a particularly formidable challenge in arid and semi-arid grasslands that characteristically support a multitude of forage species because intensity of defoliation varies among individual plants as a result of selective grazing processes. Because the more palatable or productive plants or plant species are generally defoliated more intensively than the less palatable or productive plants, preferred species often decline in abundance. This decline results from a reduction in their ability to compete with less desirable plants for critical resources such as water and nutrients. A major objective of any grazing management strategy is to prevent a shift in species composition towards an assemblage of plants that is dominated by species of lower nutritional value.
Continental, semi-arid, and highly variable. Average annual rainfall occurring in May and September (Fig. 1). Average temperatures range from 28°F in January to 96°F in July. Average minimum daily temperature varied from 52°F in January to 72°F in July.

Ranch located on the eastern edge of the southern mixed-japonicas grass prairie region of North America. Climate range sites are clay loam, clay slopes, clayey upland, and loamy bottomland, and rocky hills (Soil Conservation Service, 1984). Elevation ranges from 1338 to 1519 ft.

There are basically four grazing tactics used to balance livestock production. These tactics center around the (i) antagonistic relationship between ongoing and future animal productivity; (ii) temporal and (iii) spatial distribution of various (iv) kinds of vegetation; and (v) numbers of livestock (Gammon, 1978; Kothmann, 1980; Wilson et al., 1984). The objective of this paper is to examine the relative impact of temporal and spatial distribution (grazing systems) and numbers of animals (stocking rate) on cow/calf production and ecosystem dynamics.

MATERIALS AND METHODS

Study Area

For a more complete description of climate, soils, and vegetation at the ranch, see Heitschmidt et al. (1985).

Experimental Ranch. Continuous line depicts long-term (27-yr) monthly mean precipitation.

Fig. 1. Monthly precipitation (inches) from 1981 through 1987 at Texas Experimental Ranch. Continuous line depicts long-term (27-yr) monthly mean precipitation.

Fig. 2. Annual rates of stocking (acres/cow-year) from 1982 through 1987 for four yearlong grazing treatments.

Grazing Treatments and Livestock Management

Grazing cycle (Le., length of rest periods) in the RG treatment averaged 568 and 637 acres, respectively. Normal pastures and two herds each. Size of the HC and MC treatments were switched annually (October) between the two pastures within each treatment to minimize the potential effect of differences between pastures on herd performance. Pastures in the DR treatment averaged 270 acres during extended periods of rapid forage growth (spring), cattle were rotated slowly (65-d rest). During winter dormancy they were rotated slowly (65-d rest). While during winter dormancy they were rotated slowly (65-d rest). Elevation varied from 30 to 65 d depending upon vegetation growth rates and the physiological condition of the cows.

During winter dormancy they were rotated slowly (65-d rest). While during winter dormancy they were rotated slowly (65-d rest). Elevation varied from 30 to 65 d depending upon vegetation growth rates and the physiological condition of the cows.
to early April. Calves were weighed (unshrunk) at the 94

variations among years were the result primarily of cow

year whereas cows in the moderately stocked treatments

tively,

drought levels at the beginning of the

weaned. Conception rates were determined via rectal pal-

ation in October. Calving season, during which all calf

birth dates were recorded, extended from late December

and (iii) failure to breed,

were not included in this study.

At the end of each production year

were replaced only at the end of each production year

of time. Cows that died during a production year

supplement was supplied three times per week.

Cattle used for performance evaluations were

Hereford-Angus crossbred cows bred to fertility-tested

Charolais bulls. The breeding season extended from


The data set consisted of annual herd means for: cow

Table 1. Mean cow and

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cow Calf cow Calf cow Calf cow Calf cow Calf cow Calf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calf cow Calf cow Calf cow Calf cow Calf cow Calf</td>
</tr>
<tr>
<td>Heavy continuous</td>
<td>1089b* 922ab 227ab 1020a 373b 1045ab 514b 1020a 579b</td>
</tr>
<tr>
<td>Moderate continuous</td>
<td>1080b 924b 214b 991a 366b 1020b 485c 995a 550c</td>
</tr>
<tr>
<td>Rotational graze</td>
<td>1095b 924ab 215b 988a 350c 1021b 485c 995a 550c</td>
</tr>
</tbody>
</table>

Amount of winter supplement (20% crude protein

per cow per year were:

heavy Texas broomweed production. Averaged across

range cube) fed varied among treatments and years. In

years, amounts of supplement fed per cow per year were:

April to

& 192

July, during the period of peak live herbage standing crop; August, during the usual

winter storms or during winters following summers of

death losses and/or the occasional addition of experi-

mental animals (esophageally fistulated steers) for short

times per production year: December, prior to calving;


405

lb/cow). Production per acre was calculated-

as a repeated

measures factorial design. Herds within treatment were

were used for mean separation where appropriate

were adjusted for differences among years in number of

Tukey Q values

were applied as a repeated

Analysis of variance and analysis of covariance models.

calculate production per cow and per acre were calculated. Percentage calf

cation effects was herd within treatment (d.f.

percentage calf weaned by 90% of cows bred

These treatments were restocked to pre-

December=20.

As a result of this restriction, the

and (iv) after the second year, a bred cow failed to wean

were not included in this study.

were not included

within each production period. All data were analyzed separately for

periods of time. Cows that died during a production year

15

Decade was controlled for with the collection of annual heifer means for: cow

of the heifers and steers. From these data, weaned calf

Absolute weight fluxes were calculated by subtraction

calculated by dividing absolute flux by beginning weight (e.g.,

lb weight flux). Relative weight fluxes were calcu-

lated by dividing production per cow by annual rate of stock-

lation effects were

and covariant effects were

30

days between weigh dates. Production per cow was cal-

as a result of this restriction, the

winter storms or during winters following summers of

were replaced only at the end of each production year

they died during a production year

were not included in this study.

were not included in this study.

within each production period. All data were analyzed separately for

periods of time. Cows that died during a production year

were not included

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were not included in this study.

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were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.

were not included in this study.
Table 2. Mean cow returns using annual values of the stocking rates, amounts ing, $L0/head. Costs for repairs, fuel, and labor were assumed equal across treatments. This assumption was that prevailed from 1983 through 1986. Important items range of situations. Estimated costs for a 3000 acre $8.66/cow (includes part for calf, bull, etc.); and market-analysis of variance model. Tukey Q values were used made to expand the utility of these data across a wide weaned steer calves, $60.75/cwt for heifer calves, and range of supplemental feed, and production levels reported for 1983 through 1986 and included: $64.25/cwt for 900 lb cull cows.

All four strategies were evaluated with average cow costs/year were $416.25 for fuel, $611.25 for equipment and returns, each grazing strategy was analyzed as if it of supplemental feed, and production levels reported for were a single enterprise being operated on 3000 acres of death losses of 2.6%/yr with 10.4% of cows culled each year and enough heifer calves retained each year to equal were set at $5.20/mile for external line finces and were a single enterprise being operated on 3000 acres of land. Prices and costs used were representative of prices costs/year were $45 for the HC and MC strategies and of investment capital was assumed to be 10%/yr and in-

Across dates and years, cow weights averaged 1019, 998, 1075, and 1005 lb in the HC, MC, DR, and RG treatments, respectively. Cows in the DR treatment were consistently heavier than cows in other treatments on all dates (Table 1), although differences were not always statistically significant. Effect of weigh dates was similar in all (Table 1) although differences were not always statistically significant. Effect of weigh dates was similar in all situations. Estimated costs for a 3000 acre $8.66/cow (includes part for calf, bull, etc.); and market-analysis of variance model. Tukey Q values were used made to expand the utility of these data across a wide situations. Estimated costs for a 3000 acre $8.66/cow (includes part for calf, bull, etc.); and market-analysis of variance model. Tukey Q values were used made to expand the utility of these data across a wide
Average daily gains (ADG) of calves within a period were significant. From April to June, ADGs were greater-than-normal forage availability, as a result of cows being lighter than normal in April. Average cow weights in April (Table 3) were related primarily to the combined effects of weather conditions and stocking密度. When weather conditions were above-average, they increased equally, in the HC, MC, DR, and RG treatments, respectively, in the DR treatment. The absence of significant treatment, year interaction effect was not significant. Averaged across years, there was little difference among treatments in calf weights in April and major differences thereafter in that weights in June, August, and October weights. Although birth dates did not vary significantly among treatments in the current study, weaned calf crop, production/acre from 1982 through 1987 in four yearlong grazing treatments. Covariants were December, April, and October weights. Although birth dates did not vary significantly among treatments in the current study, weaned calf crop, production/acre from 1982 through 1987 in four yearlong grazing treatments.
seven covariants, only actual and percent weight change during the calving season (December-April) were significant. These analyses showed that when conception rates were adjusted for weight change from December to April, conception rates in the HC, DR, and RG treatments decreased slightly, conception rate in the MC treatment increased slightly, and differences between treatments were no longer significant. However, the presence of significant year and treatment × year interaction effects revealed that these covariates did not adequately account for all differences among treatments in conception rates.

Neither cow nor calf death losses varied significantly among treatments or years. Across all years and treatments, cow death losses averaged 2.6% whereas calf death losses averaged 8.3%.

Weaned calf crop (Table 3) did not vary significantly among treatments, although it was greatest in the DR treatment and least in the RG treatment. It did, however, vary significantly among years (Table 4). The lowest calf crop weaned occurred in 1985 (73%), following the 1984 drought when conception rates averaged 84%, and the highest weaned calf crop occurred in 1986 (89%), following the 97% conception rate achieved in 1985. The treatment × year interaction effect was not significant.

Production per cow was significantly greater in the DR than RG treatment (Table 3) with the HC and MC treatments intermediate and not significantly different from either the DR or RG treatments. Generally, production per cow followed a standard stocking rate response in that more pounds of calf were produced per cow in the moderately stocked (MC and DR) than in the heavily-stocked treatments (HC and RG). Averaged across treatments, production per cow varied significantly among years and ranged from 415 lb/cow in 1985 to 515 lb/cow in 1986 (Table 4). These data were directly related to variation among years in forage production and its effects on conception rates. The year × treatment interaction was not significant.

Production per acre was significantly different among all treatments when averaged across years (Table 3). Production per acre also followed standard stocking rate response patterns wherein the heavily-stocked treatments (HC and RG) produced more pounds of calf per acre than the moderately-stocked treatments (MC and DR). Significant differences also occurred among years with the across treatments average being lowest in 1985 (29.5 lb/acre) and greatest in 1986 (41.6 lb/acre). These differences were directly related to variation among years in forage production and its effects on conception rates.
98 years were nonsignificant. However, as with the livestock in the HC treatment. This agrees with previous economic analyses (Whitson et al. 1982) of the HC, MC, and variation in returns among years and treatments (Fig. 4), in the DR treatment the range was only from $3.45/acre significantly less than all other years, which averaged $8.43/acre and $95.78/cow in the HC treatment while ranged from 

Net returns in 1985 ($17.46/cow and $1.26/acre) were significant. For example, net returns per acre when averaged over the 6-yr study, average residual returns (Le., net returns to land, management, and profit) per cow averaged $60.81, $69.57, $93.12, and $62.72/yr in the HC, MC, DR, and RG treatments, respectively. Net returns reflected the average effect of range condition (fair vs. good) on annual forage production, estimated productivity of an area (range site) and the kinds and numbers of plants present (range condition). Because range site composition affects livestock production is an integrated product of a quantity and quality of forage produced and consumed. Thus, any interpretive conclusions from the results of this study must be based first on the probable cause livestock production is an integrated product of a forage reserve must be accumulated annually in most a forage reserve must be accumulated annually in most production (range condition) or type of grazing system, 

As to forage quality, previous research in the RG and MC treatments (Heitschmidt et al., 1987) and the HC and RG treatments than the moderately stocked MC treatments (Heitschmidt et al., 1989) has shown that differences in quality are most substantial. For example, Heitschmidt et al. (1985) reported annual forage production in the HC treatment (fair condition) averaged 2777, 2625, and 2236 lb/acre, respectively. Assuming these estimates were the inherent potential productivity of green tissue (high quality), there were greater amounts of forage produced are the inherent potential productivity of green tissue (high quality), there were greater amounts of forage produced and consumed, were minor, according to recent diet quality studies in the RG and MC treatments (Walker et al., 1988). Results showed, however, that nutrient intake was periodic less in the RG (McKoim, 1987) and HC treatments (Pinchak et al., 1988) treatments than in the MC treatments. These differences were attributed to differences in quality of senesced tissue (low quality) in the MC than the HC and RG treatments.

Differences between treatments in quantity and quality are most substantial. For example, Heitschmidt et al. (1985) reported annual forage production in the HC treatment (fair condition) averaged 2777, 2625, and 2236 lb/acre, respectively. Assuming these estimates were the inherent potential productivity of green tissue (high quality), there were greater amounts of forage produced and consumed, were minor, according to recent diet quality studies in the RG and MC treatments (Walker et al., 1988). Results showed, however, that nutrient intake was periodic less in the RG (McKoim, 1987) and HC treatments (Pinchak et al., 1988) treatments than in the MC treatments. These differences were attributed to differences in quality of senesced tissue (low quality) in the MC than the HC and RG treatments. As a result, economic risk was least in the DR treatment and greatest in the HC and RG treatments from 1961 through 1978.
and 16-pasture, 1-herd rotational grazing (RG) stocked at a very heavy rate. The data from the study show that stocking rate was the major factor affecting livestock production and economic returns because, as stocking rate was increased, average production and residual returns per cow declined, whereas average production and residual returns per acre increased (Fig. 2 and 3). Moreover, the results show that annual production stability also tended to decrease as rate of stocking was increased except at the highest stocking rate (RG), whereby livestock production was continually depressed. Quite simply, the results show that in semi-arid and arid rangelands grazed yearlong, it is not possible to continually stock at heavy rates without encountering increased financial risk because of the need to periodically destock or provide a substitute feed in the absence of sufficient amounts of forage.

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